Fishery Data Series No. 07-11

Use of Three Microhabitats by Juvenile Coho Salmon in Jordan Creek During the Winter, 2004–2005

by

Ryan J. Briscoe

March 2007

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Department of Fish and Game	ADF&G
Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Closed population mark–recapture experiments were conducted at three different sites in Jordan Creek during both the early and late winter of 2004–2005. An abundance estimate of 890 (SE = 220) juvenile coho salmon $\leq$ 76 mm was calculated for site 1, a glide section, during the early winter. No abundance estimate was obtained for site 1 during the late winter. Coho salmon captured at site 2, a beaver pond, were stratified into two size strata resulting in an estimated pooled abundance of 1,920 (SE = 114) juvenile coho salmon during the early winter. An abundance estimate of 807 (SE = 56) juvenile coho salmon $\geq$ 66 mm was calculated for site 2 during the late winter. Site 3, a man-made pond, had an estimated pooled abundance of 577 (SE = 150) juvenile coho salmon during the early winter and an estimated abundance of 25 (SE = 6) juvenile coho salmon $\leq$ 93 mm during the late winter. Abundance estimates for some size classes were not calculated because of low recapture numbers. The majority of recaptured fish were captured at their original site, indicating that most fish do not migrate in the winter. Some migration does occur, as a few juvenile coho salmon migrated among sites between the early and late winter periods. One juvenile coho salmon migrated among two sites between the late winter sampling periods of the two sites. A few previously coded wire tagged coho salmon were captured, indicating that some coho salmon reinvade freshwater after smolting and residing in the estuary during the summer. Partial finclips were the easiest marks to observe, anal and caudal dye marks were not effective, and freeze brands were observable in the short term but difficult to see when fish emigrated through the weir months later. Results of this study indicate that an open population model that allows for migration would provide a more appropriate estimator of abundance than a closed model. This would require the use of unique tags (i.e. PIT tags) for each individual fish instead of batch marks. Microhabitats used by overwintering coho salmon must be thoroughly quantified for the entire Jordan Creek system before valid conclusions can be drawn regarding the importance of specific types of habitat.

Key words: Southeast Alaska, juvenile coho salmon, *Oncorhynchus kisutch*, Jordan Creek, Juneau, habitat, mark–recapture, closed population, finclip, dye, freeze brand, hole punch, overwinter, abundance, migration, minnow trap.

INTRODUCTION

Coho salmon *Oncorhynchus kisutch* hatch and generally rear for one to two years in their natal freshwater systems before entering saltwater. These freshwater systems are dynamic and the quantity and quality of habitat available to juvenile coho salmon within these systems changes over the course of time. The habitat available to juvenile coho salmon in the freshwater environment can have a significant impact on freshwater survival and production of coho salmon (Tschaplinski and Hartman 1983; Heifetz et al. 1986). The quality and quantity of available winter rearing habitat is especially critical to the survival of juvenile coho salmon because freezing and low water flows often reduce the amount of habitat that is typically available at other times of the year.

A study was conducted on Jordan Creek to investigate the use of specific overwintering habitats by juvenile coho salmon. This study did not attempt to assess the quality of habitat for each of the microhabitat types represented. The sites were chosen for ease of access and diversity of the habitat. They were not chosen using standard sampling theory. Therefore, no statistical inference can be extended to any other location in Jordan Creek. Furthermore, this study did not attempt to compare habitat quality between the specific sites studied. It is inappropriate to use animal density as a measurement of habitat quality unless certain criteria are met (Van Horn 1983). The seasonal nature of the environment and the lack of information regarding long-term migration would require a more rigorous study.

This study did assess the feasibility of using mark–recapture experiments to estimate abundance of rearing coho salmon in a microhabitat over the course of a few days. Because certain model assumptions might have been violated, the results herein should be interpreted cautiously. Mark–recapture experiments were conducted within three selected Jordan Creek microhabitats during the early and late winter in 2004–2005 to estimate the abundance of juvenile coho salmon using these habitats. This report summarizes the results of those experiments and evaluates the plausibility of using mark–recapture techniques for future fish habitat studies within Jordan Creek. A more detailed account of Jordan Creek coho production can be found in other reports (Lum and Glynn *In prep*; Briscoe et al. *In prep*).

Objectives for project were:

1. Estimate abundance of juvenile coho salmon overwintering in three different microhabitats;

2. Assess the feasibility and efficiency of trapping and marking methodology to determine if it is plausible to use in a future project designed to thoroughly quantify the use of microhabitats by juvenile coho salmon in Jordan Creek during the winter.

STUDY AREA

Jordan Creek (Alaska Department of Fish and Game [ADF&G] Catalog Number 111-50-10620) is located approximately 11 km northwest of Juneau, Alaska, on the Juneau road system (Figure 1). Jordan Creek has historically produced coho salmon, pink salmon *O. gorbuscha*, chum salmon *O. keta*, sockeye salmon *O. nerka*, cutthroat trout *O. clarki*, steelhead *O. mykiss*, and Dolly Varden char *Salvelinus malma*. Jordan Creek originates from a ground water source near the base of Thunder Mountain, meanders through the Mendenhall Valley for about 4.8 km, and empties into the Mendenhall Wetlands State Game Refuge. Three sites were selected for this study. A section consisting mostly of glide habitat (site 1) located between coordinates N 58° 23.304’ W 134° 33.670’ and N 58° 23.266’ W 134° 33.719’ (WGS-84, Figure 1) upstream of Amalga Street was selected because it is a common spawning area. A densely-vegetated beaver pond (site 2), located between N 58° 22.755’ W 134° 33.868’ and N 58° 22.727’ W 134° 33.887’ (WGS-84, Figure 1), was selected because of its probable rearing importance. The remaining site (site 3) was a sparsely-vegetated, man-made pond directly upstream of the culverts passing under Yandukin Drive between N 58° 21.535’ W 134° 34.598’ and N 58° 21.519’ W 134° 34.531’ (WGS-84, Figure 1).

METHODS

MARK–RECAPTURE

Two-event mark–recapture experiments were used to estimate the population abundance of juvenile coho salmon within each study site. Separate mark–recapture experiments were conducted at each site during early winter and at site 2 and 3 during late winter (Table 1). At site 1, the late winter experiment was restricted to marking and measuring coho salmon $\geq$ 65 mm.

Table 1.–Dates of mark–recapture experiments at Jordan Creek during the winter of 2004–2005.

Site number	Early winter	Late winter
1	November 22–29	March 22 (marking only)
2	December 6–10	March 14–18
3	December 14–17	March 7–11

Fifteen uniquely numbered minnow traps with 6 mm wire mesh were baited with salmon eggs and evenly distributed throughout each study site. The eggs were covered with nylon mesh to prevent them from being eaten. Traps were set in the morning on the first day of the experiment and then sampled for captured fish the following day (1st event). Captured coho salmon were placed in an anesthetic bath of tricaine methane-sulfonate (MS-222), sodium bicarbonate, and water. Each coho salmon was counted, measured to the nearest mm, and marked with one of many possible batch marks specific to each site and each time period (Table 2). These marked coho salmon were released into the same area they were captured.

Marks included fluorescent pink dye injected into anal fins (AD), fluorescent pink dye injected into lower caudal fins (LCD), partially-clipped lower caudal fins (LCC), partially-clipped upper caudal fins (UCC), “J” freeze brands, “V” freeze brands, and “T” freeze brands (Table 2). All dye marks were injected using a pan jet microinjector, fins were partially clipped with scissors, and brands were applied using brass letters that were frozen using compressed carbon dioxide (CO_2) as described by Bryant and Walkotten (1979). The brand was dipped in acetone after it was frozen to prevent the brand from sticking to the fish’s flesh. Brands were located above the lateral line and

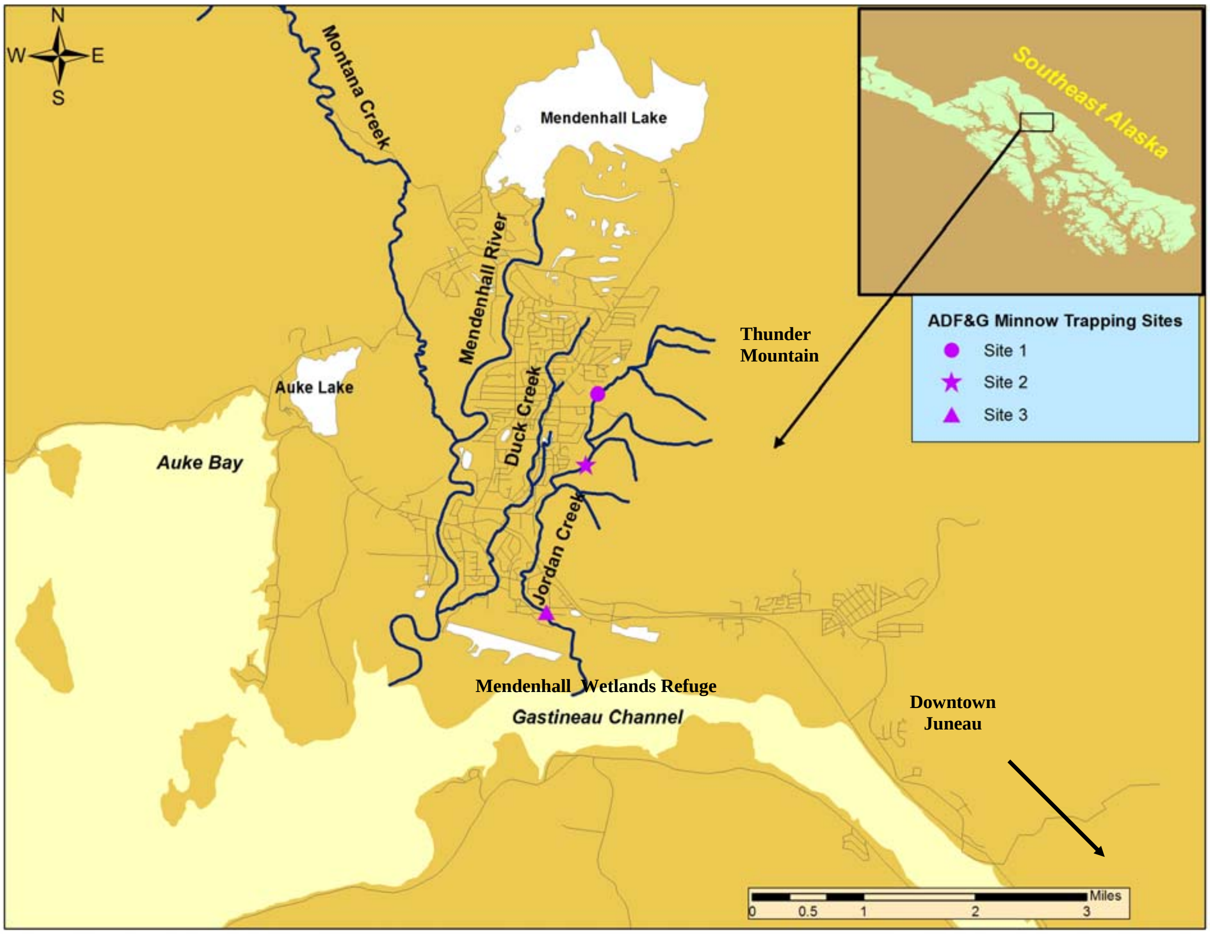

Figure 1.–Map showing the location of the three minnow trapping sites on Jordan Creek in the Mendenhall Valley.

Table 2.–Unique batch marks given to juvenile coho salmon at each site during the winter of 2004–2005 (AD = anal fin dye mark, LCD = lower caudal fin dye mark, LCC = lower caudal finclip, UCC = upper caudal finclip, LCP = lower caudal fin punch, UCP = upper caudal fin punch)**.**

	Primary mark	Secondary mark
Early winter		
Site 1	AD	-
Site 2	LCD, LCC	-
Site 3	UCC	-
Late winter		
Site 1	"J" brand	-
Site 2	"V" brand	LCP
Site 3	"T" brand	UCP

- indicates no mark was given

anterior of the dorsal fin. Small holes were punched in either the lower (LCP) or upper (UCP) caudal fin as secondary marks to assess tag retention of some brands (Table 2).

Traps were set again after a hiatus of at least 36 hours. This allowed fish to recover from the handling and anesthetic. Traps were checked for marked coho salmon the day after they were reset (2nd event). The 2nd event conducted at site 1 during the early winter was designated as another marking event because of the low number of recaptured fish. The two marking events were pooled and designated as the 1st event, and a subsequent recapture event was designated as the 2nd event. Marked and unmarked coho salmon were counted and measured to assess whether model assumptions were valid. Unmarked coho salmon captured during the 2nd event were marked to increase the probability of detecting migration between sites. An anticipated benefit of the differential marking was that we could count marked juveniles emigrating through the weir operated in spring 2005. All other fish species captured were examined for tags, counted, and released. Any adipose-clipped coho salmon were sacrificed to obtain the coded wire tag (CWT). Daily water temperature was recorded at each site to the nearest 0.5 ºC.

ABUNDANCE ESTIMATES AND ANALYSIS

The Petersen model (Seber 1982) was used to estimate the abundance of juvenile coho salmon at each site. The assumptions for this model were:

1) The population is closed to immigration or emigration;
2) All fish have the same probability of being caught in the first event, or every fish has an equal probability of being sampled during the second event, or marked and unmarked fish mix completely;
3) Marking does not affect the catchability of a fish;
4) Fish do not lose their marks in the time between the two samples;
5) All marks are reported when recovered.

The modified Chapman-Petersen model estimator (Seber 1982) was used to calculate an estimated abundance at each site during each winter period:

$$\hat{N} = \frac{(n_1+1)(n_2+1)}{(m_2+1)} - 1 \qquad (1)$$

$$SE[\hat{N}] = \sqrt{\frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)}} \qquad (2)$$

where:

$\hat{N}$ = estimated abundance of juvenile coho salmon;

n_1 = number of juvenile coho salmon caught in 1st event;

n_2 = number of juvenile coho salmon caught in 2nd event;

m_2 = number of marked juvenile coho salmon recaptured in 2nd event.

The relative precision of this estimate was calculated using:

$$RP = SE[\hat{N}] / \hat{N} * 1.96 \qquad (3)$$

Assumption 1 was addressed by enclosing site 1 during the early winter with small-mesh seine nets. Fish populations at the other two sites were assumed to be closed to migration because cold water temperatures have been documented to slow the activity and movement of coho salmon during the winter (Hartman 1965; Bustard and Narver 1975) and because high flows probably did not force fish out of the ponds. Kolmogorov-Smirnov (KS) tests (Zar 1999) were used to test for violations in assumption 2, specifically to determine if traps were selecting for fish of certain lengths (Appendix A1). If size selectivity did occur, length data was stratified into size classes and a Chapman-Peterson estimate of abundance was obtained for each size class. Strata breaks were determined by comparing the cumulative length frequency distributions of coho salmon marked (marks) in the 1st event against those of coho salmon recaptured (recaptures) in the 2nd event. Breaks were identified as the length that corresponded to the maximum difference, represented by the maximum d-statistic, in cumulative length frequency between marks and recaptures. Stratified abundance estimates for each size class were summed to obtain a pooled estimate of abundance. The use of batch marks prevented testing of how marks affected catchability (assumption 3). The use of secondary marks allowed us to assess whether fish retained their marks (assumption 4), and trained staff ensured that all marks were reported when recovered (assumption 5).

RESULTS

EARLY WINTER

Site 1 (Amalga Street)

Juvenile coho salmon captured averaged 76 mm and ranged from 44 to 113 mm (Figure 2). A total of 376 coho salmon were captured and marked in the 1st event, 88 juvenile coho salmon were captured during the 2nd event, and 16 of those 88 had marks from the 1st event (Table 3). Cumulative length frequency distributions of fish captured in the 1st event (marks) and those recaptured in the 2nd event (recaptures) were not significantly different (KS test, D_{max}= 0.313, P = 0.09; Figure 3) although they were visually different. There was a significant difference (KS test, D_{max}= 0.239, P < 0.005; Figure 4) between length distributions of marks and those captured in the 2nd event (captures). The visual difference between length frequencies of marks and recaptures and the fact that the KS test was nearly significant suggested that stratifying the data might result in a less biased abundance estimate. The length data was organized into two strata: $\leq$ 76 mm and $\geq$ 77 mm. There were 188 coho salmon $\leq$ 76 mm and 188 coho salmon $\geq$ 77 mm captured during the 1st event (Table 3). During the 2nd event, 65 coho salmon $\leq$ 76 mm and 23 coho salmon $\geq$ 77 mm were captured; 13 of the 65 and 3 of the 23 fish were recaptures (Table 3). The estimated abundance of coho salmon $\leq$ 76 mm was 890 (SE = 196, RP = 43%; Table 4). The abundance of coho salmon $\geq$ 77 mm was not estimated because of the low number of recaptures. A small sample K-S test was performed to compare the length distribution of recaptures to that of captures. This test failed to reject the null hypothesis (D_{max} = 0.125, P = 0.955), implying that there was equal probability of capture in the first event. However, the small sample size (16 recaptures) suggested there may not have been enough power to detect a difference if one did exist. Therefore, the abundance of all fish using pooled data was not estimated.

Site 2 (Beaver Pond)

Juvenile coho salmon captured averaged 84 mm and ranged from 47 to 145 mm (Figure 5). There were 556 coho salmon captured and marked during the 1st event, 617 were captured during the 2nd event, and 183 of the 617 had marks from the 1st event (Table 3). Cumulative length frequency distributions of fish captured in the 1st event and those recaptured in the 2nd event were significantly different (KS test, D_{max}= 0.16, P < 0.002; Figure 6). There was also a significant difference between cumulative length frequency distributions of fish captured in the 1st event and those captured in the 2nd event (KS test, D_{max}= 0.15, P < 0.0001; Figure 7). These results indicated there was size-selectivity during the 2nd event. Length data was organized into two strata: $\leq$ 93 mm and $\geq$ 94 mm. There were 375 fish $\leq$ 93 mm and 181 fish $\geq$ 94 mm captured during the 1st event, and 498 $\leq$ 93 mm and 119 $\geq$ 94 mm captured during the 2nd event; 153 of the 498 and 30 of the 119 were recaptures (Table 3). The estimated abundance of coho salmon was 1,217 fish $\leq$ 93 mm (SE = 63) and 704 fish $\geq$ 94 mm (SE = 98; Table 4). The pooled estimate was 1,921 fish (SE = 116, RP = 12%; Table 4).

Site 3 (Yandukin Drive)

Juvenile coho salmon captured averaged 114 mm and ranged in size from 62 to 195 mm (Figure 8). There were 132 coho salmon captured and marked in the 1st event, 103 captured in the 2nd event, and 30 of the 103 had marks from the 1st event (Table 3). Cumulative length frequency distributions of fish captured in the 1st event and those recaptured in the 2nd event were significantly different (KS test, D_{max}= 0.28, P < 0.03; Figure 9), but cumulative length frequency distributions of fish captured in the 1st event and those captured in the 2nd event were not significantly different (KS test, D_{max}= 0.06, P = 0.95; Figure 10). This indicated that size selectivity occurred during both sampling events. Data was organized into two strata: $\leq$ 112 mm and $\geq$ 113 mm. There were 60 fish $\leq$ 112 mm and 72 fish $\geq$ 113 mm captured during the 1st event, and

Table 3.–Number of juvenile coho salmon captured and marked during the 1st event, number of coho salmon captured during the 2nd event, and number of coho salmon that were recaptured in the 2nd event of the mark–recapture experiment at each site for the early winter sample period.

	1st Event	2nd Event	
	Captured and marked	Captured	Recaptured
Site 1			
≤ 76 mm	188	65	13
≥ 77 mm	188	23	3
Total	376	88	16
Site 2			
≤ 93 mm	375	498	153
≥ 94 mm	181	119	30
Total	556	617	183
Site 3			
≤ 112 mm	60	49	22
≥ 113 mm	72	54	8
Total	132	103	30

Table 4.–Estimates of juvenile coho salmon abundance $(\hat{N})$ during the early winter for each study site at Jordan Creek in 2004.

	$\hat{N}$	SE	$\hat{N}$	SE	Pooled $\hat{N}$	SE	RP (%)
Site 1	≤ 76 mm		≥ 77 mm				
	890	196	-[a]	-[a]	-	-	43[b]
Site 2	≤ 93 mm		≥ 94 mm				
	1,217	63	704	98	1,921	116	12
Site 3	≤ 112 mm		≥ 113 mm				
	132	17	445	120	577	122	41

[a] No estimate was calculated.

[b] The relative precision is for only one strata.

49 ≤ 112 mm and 54 ≥ 113 mm captured during the 2nd event; 22 of the 49 fish and 8 of the 54 were recaptures (Table 3). The estimated abundance of coho salmon was 132 fish ≤ 112 mm (SE = 17) and 445 ≥ 113 mm (SE = 120); the pooled estimate was 577 (SE = 122, RP= 41%; Table 4).

Late Winter

Site 1 (Amalga Street)

Juvenile coho salmon captured averaged 71 mm and ranged in size from 45 to 119 mm (Figure 2). Eighty-three of the 240 coho salmon captured were less than 65 mm and were not marked (Table 5). Abundance was not estimated because a 2nd event was not conducted.

Site 2 (Beaver Pond)

Juvenile coho salmon captured averaged 77 mm and ranged in size from 48 to 137 mm (Figure 5). There were 400 coho salmon captured and marked during the 1st event, 332 captured in the 2nd event, and 93 of those 332 had marks from the 1st event (Table 5). Cumulative length frequency distributions of fish captured in the 1st event and those recaptured in the 2nd event were significantly different (KS test, D_{max}= 0.21, P < 0.002; Figure 11). There was no significant difference between cumulative length frequency distributions of fish captured in the 1st event and those captured in the 2nd event (KS test, D_{max}= 0.06, P = 0.60; Figure 12). Theses results indicate that size-selectivity occurred in both sampling

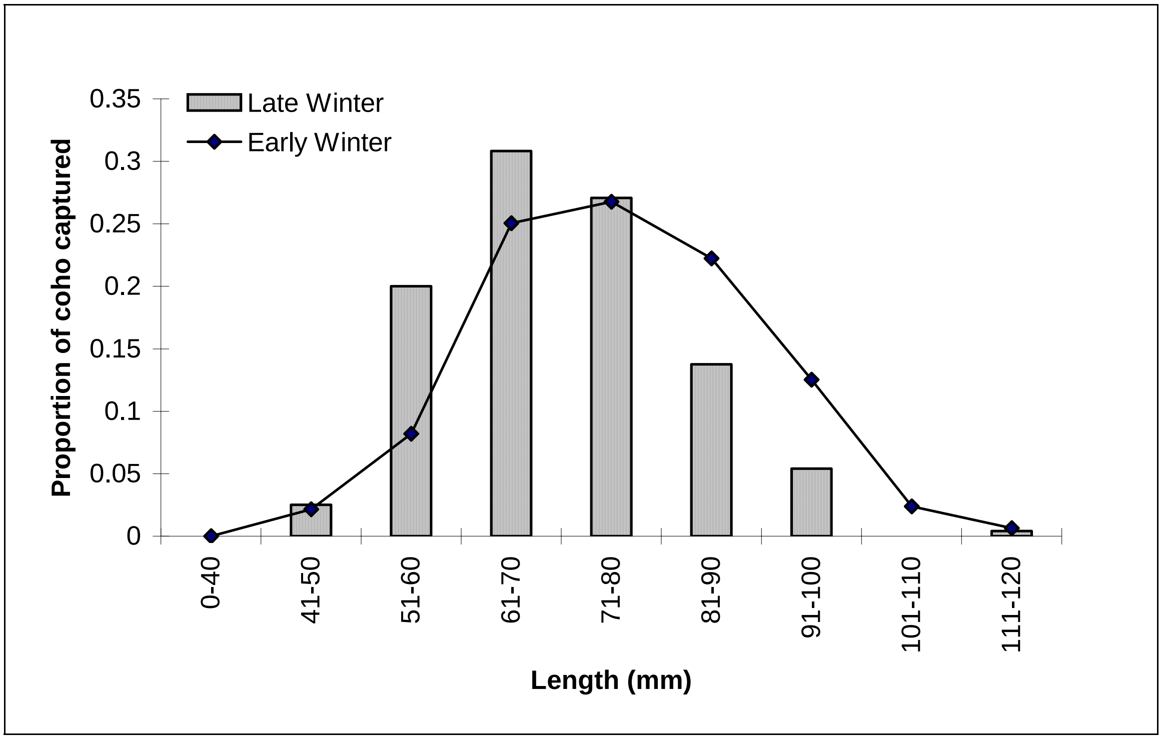

Figure 2.–Length frequency distributions of juvenile coho salmon captured at site 1 during the early and late winter.

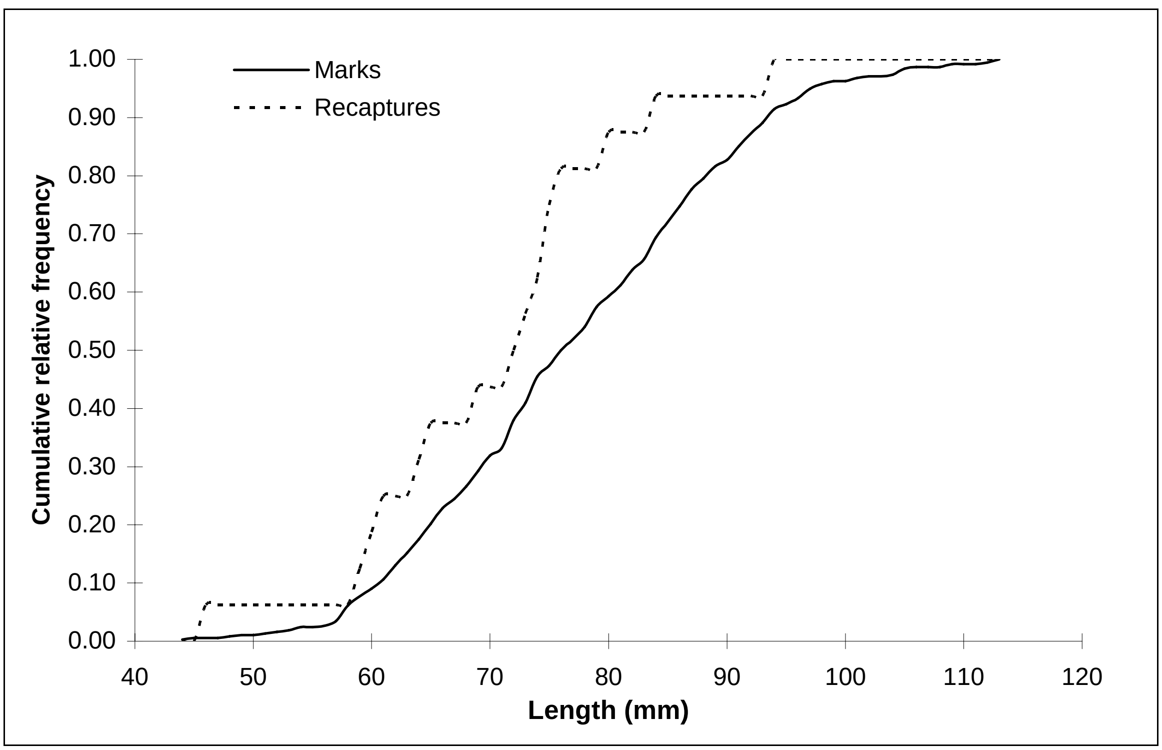

Figure 3.–Cumulative length frequency distributions of marks and recaptures at site 1 during the early winter.

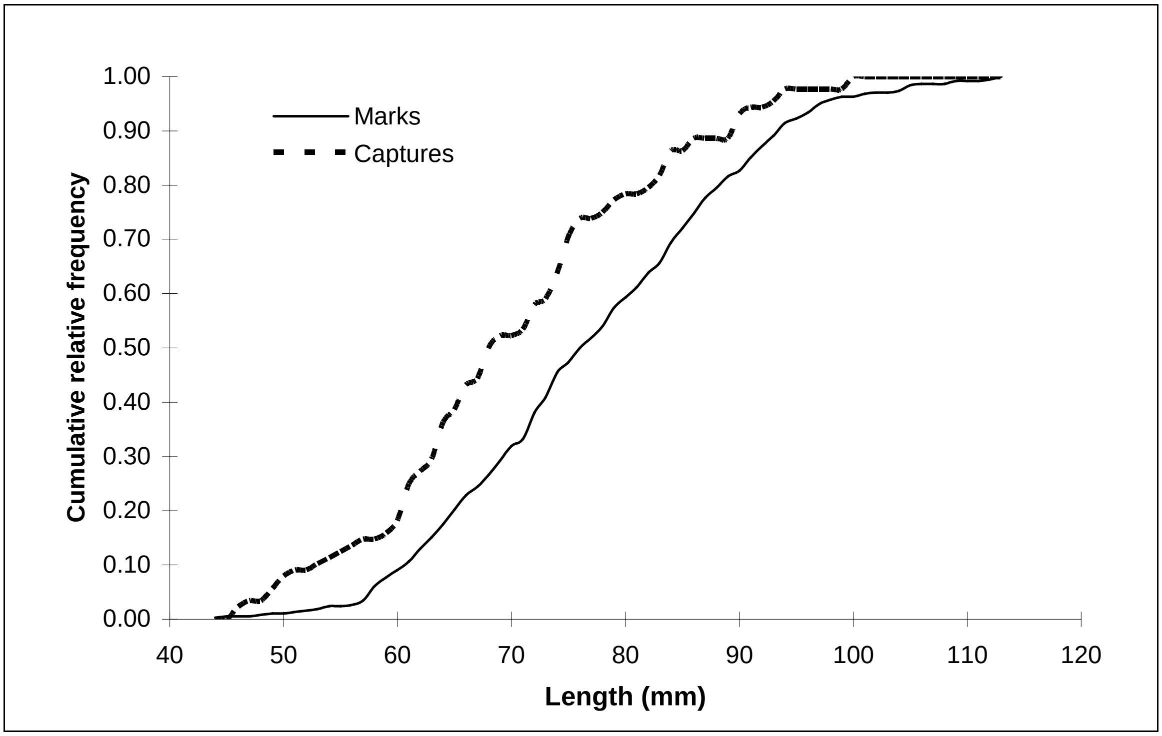

Figure 4.–Cumulative length frequency distributions of marks and captures at site 1 during the early winter.

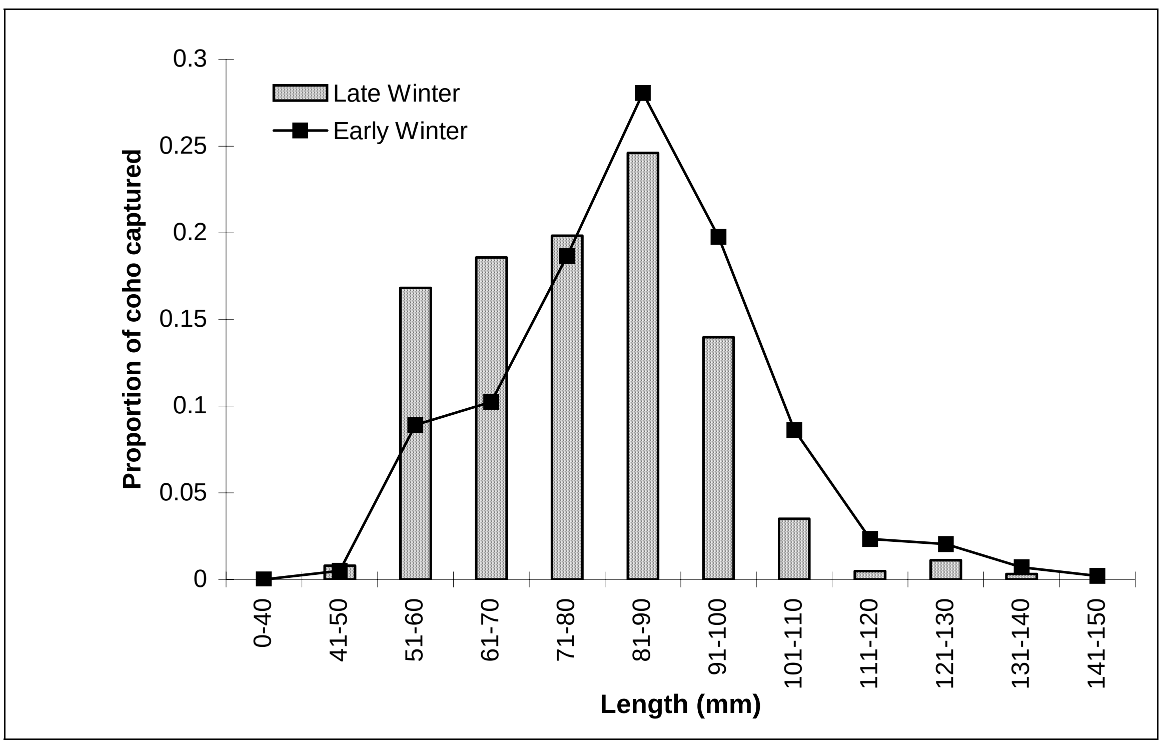

Figure 5.–Length frequency distributions of juvenile coho salmon captured at site 2 during the early and late winter.

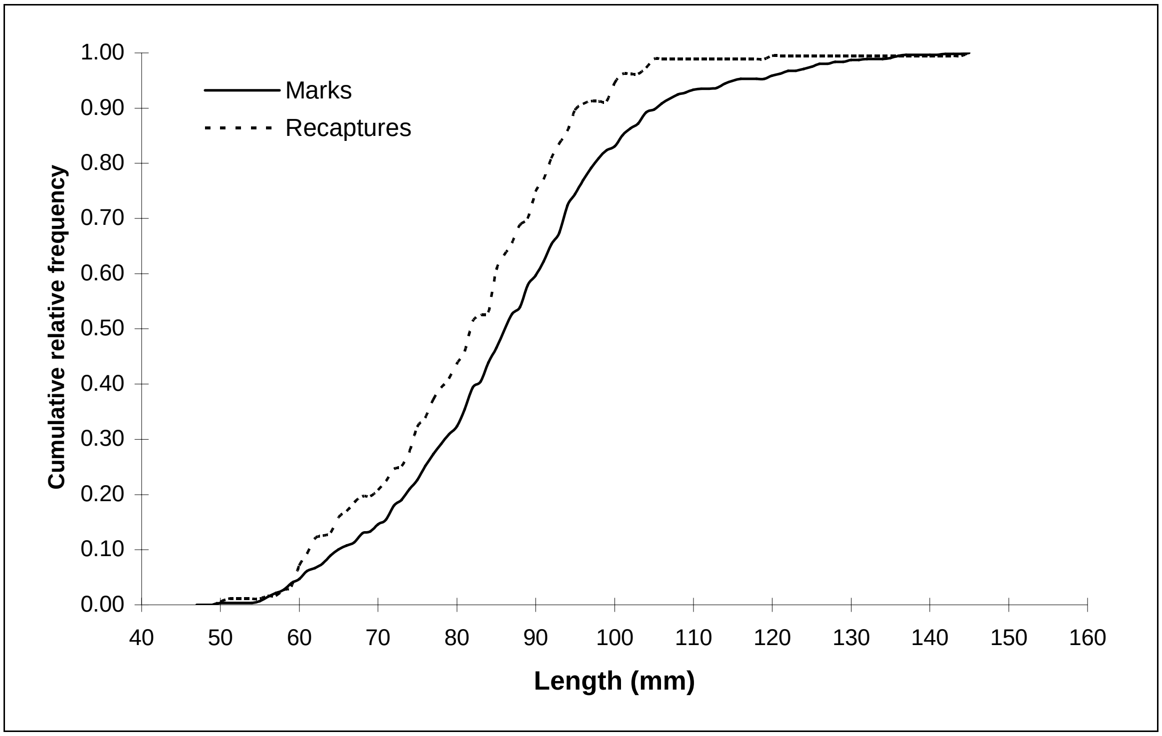

Figure 6.–Cumulative length frequency distributions of marks and recaptures at site 2 during the early winter.

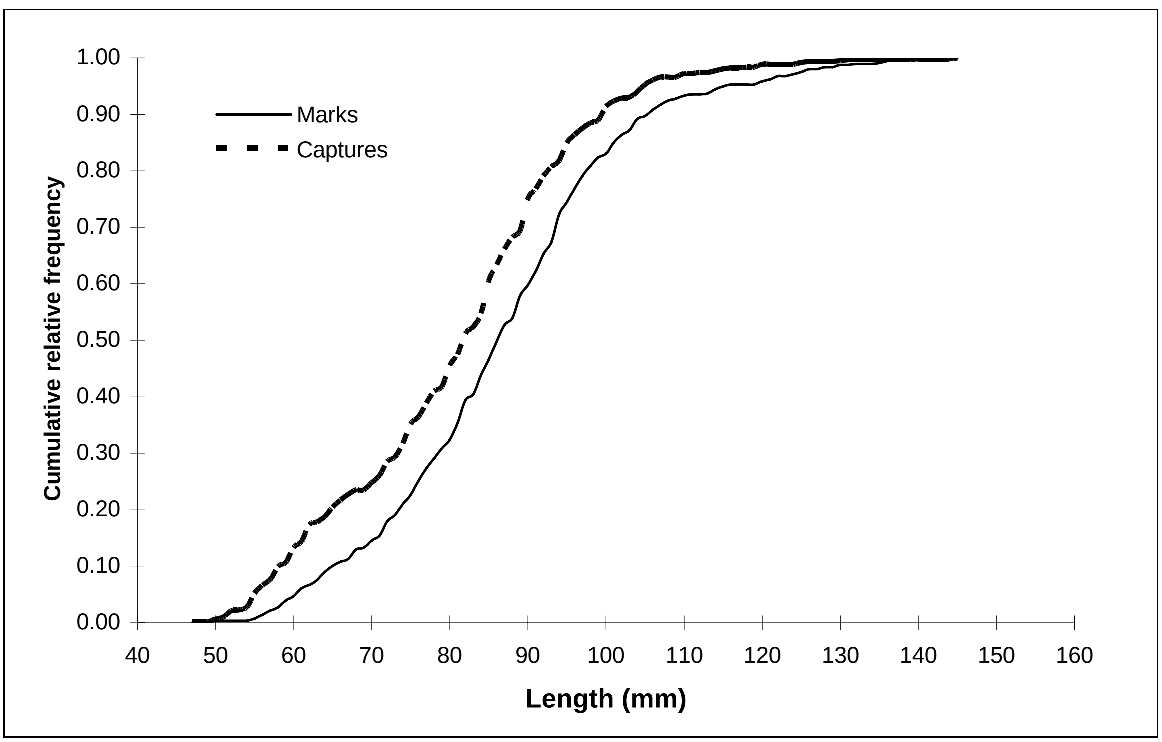

Figure 7.–Cumulative length frequency distributions of marks and captures at site 2 during the early winter.

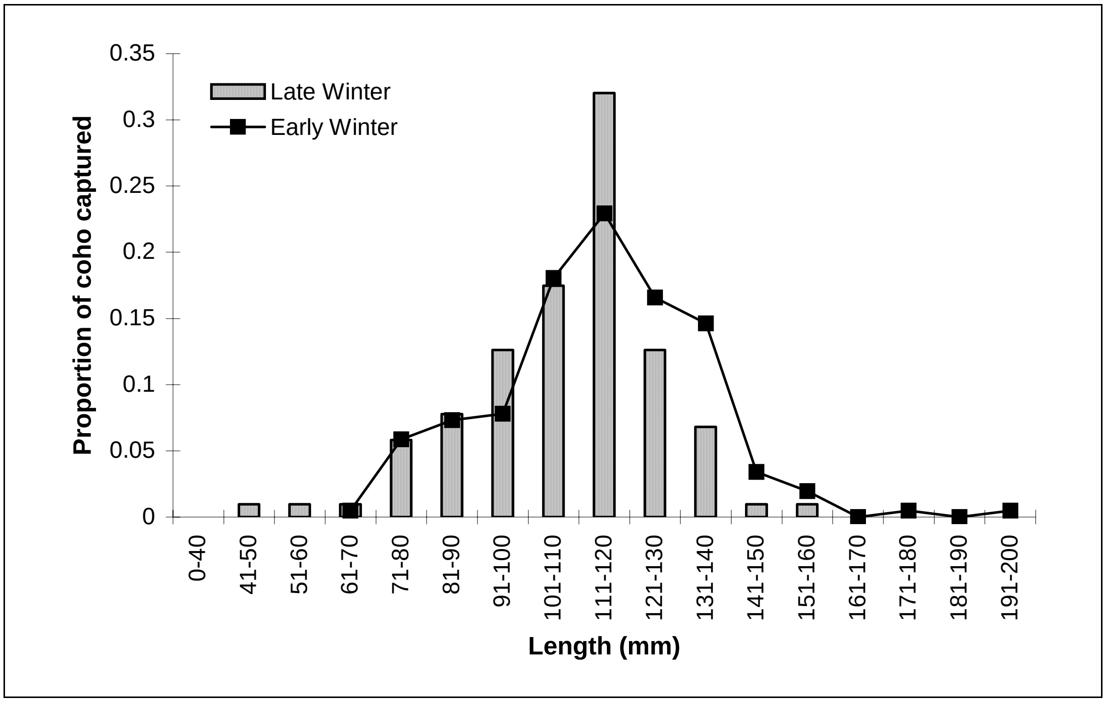

Figure 8.–Length frequency distributions of juvenile coho salmon captured at site 3 during the early and late winter.

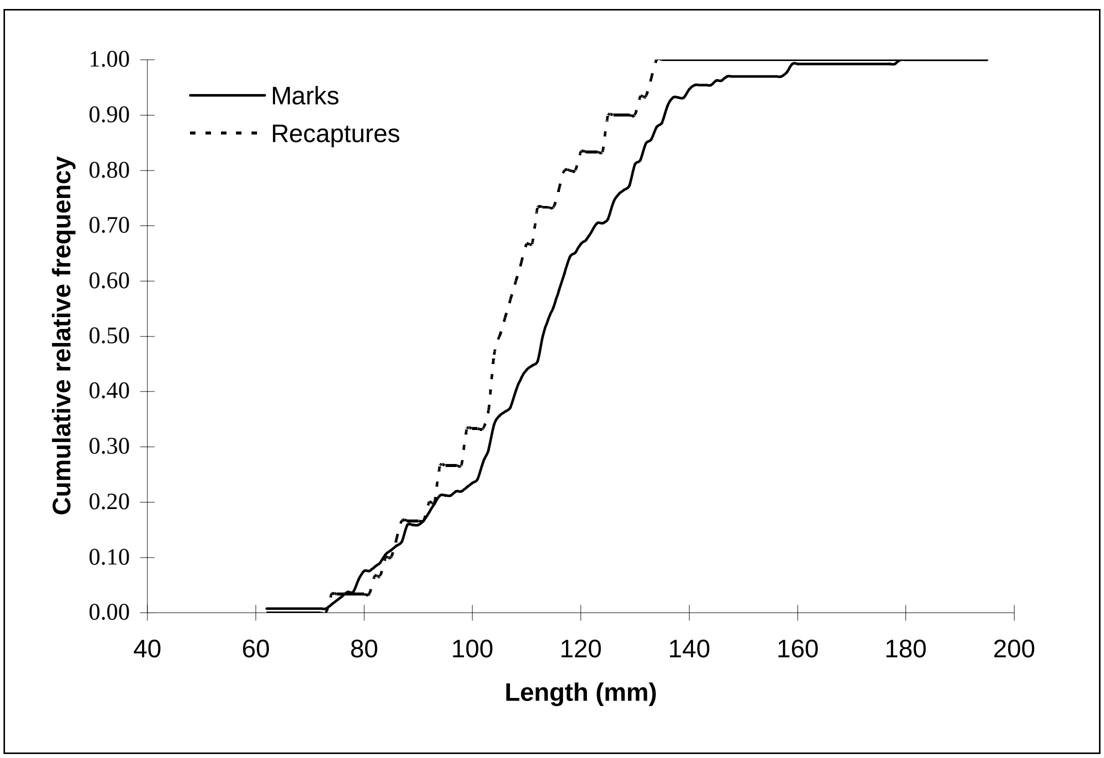

Figure 9.–Cumulative length frequency distributions of marks and recaptures at site 3 during the early winter.

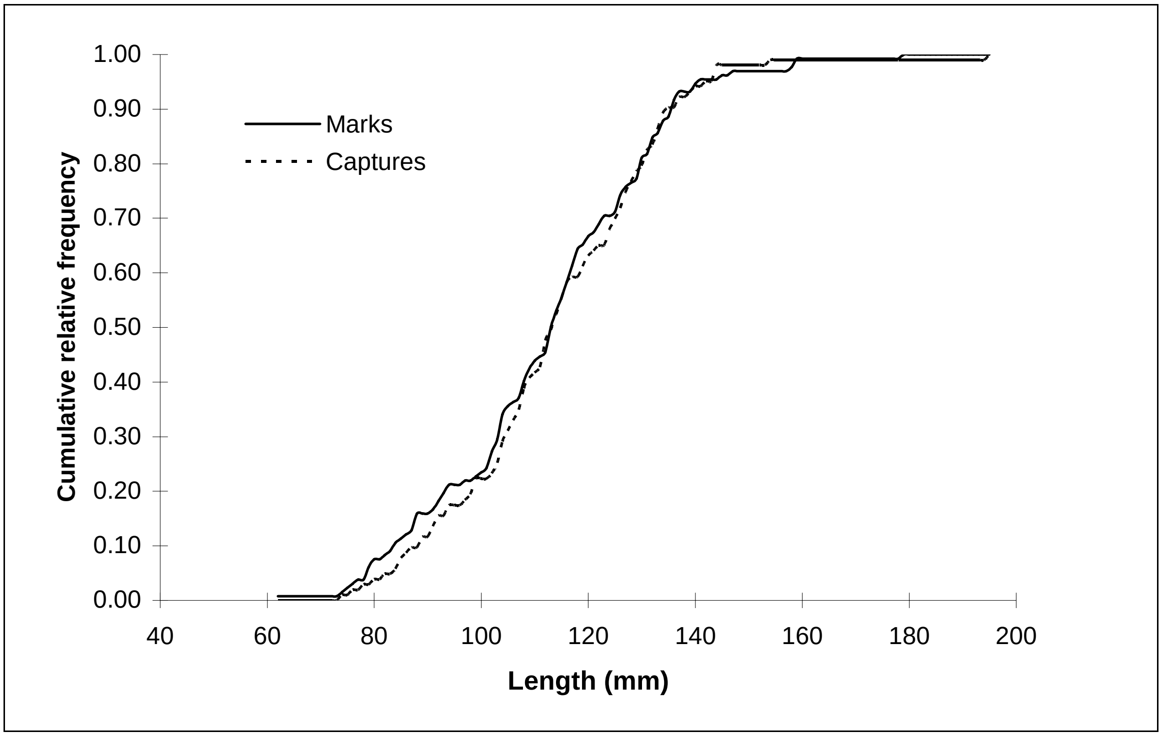

Figure 10.–Cumulative length frequency distributions of marks and captures at site 3 during the early winter.

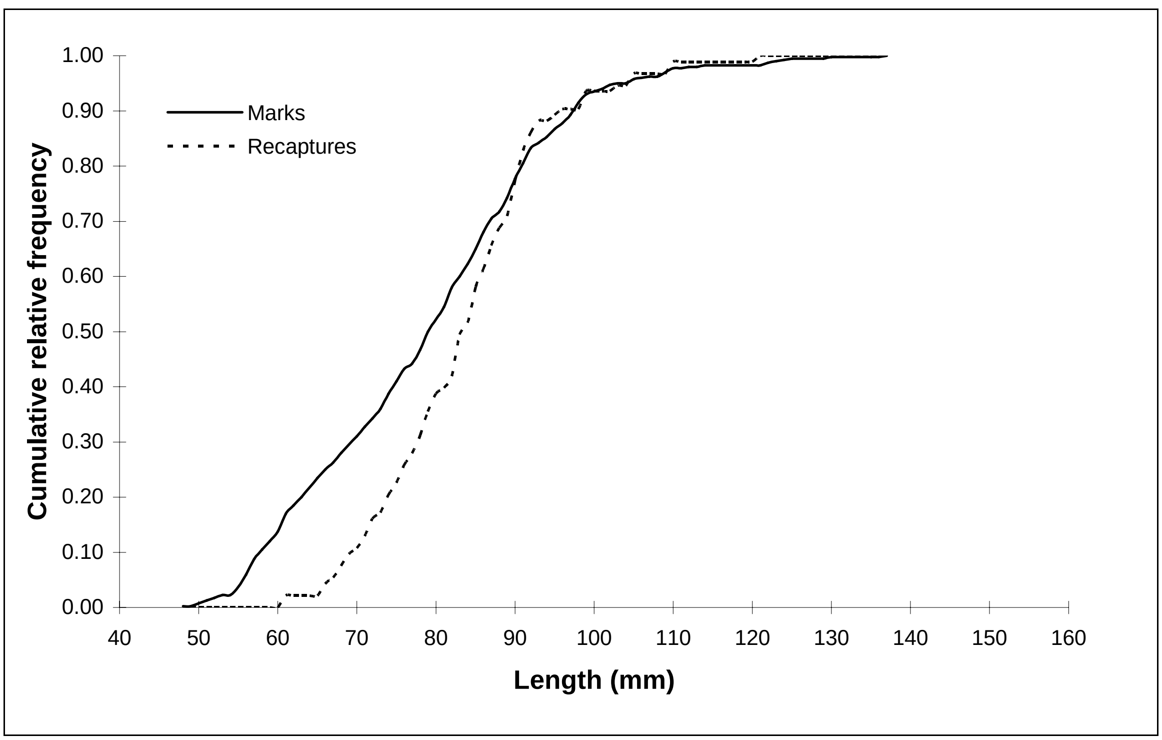

Figure 11.–Cumulative length frequency distributions of marks and recaptures at site 2 during the late winter.

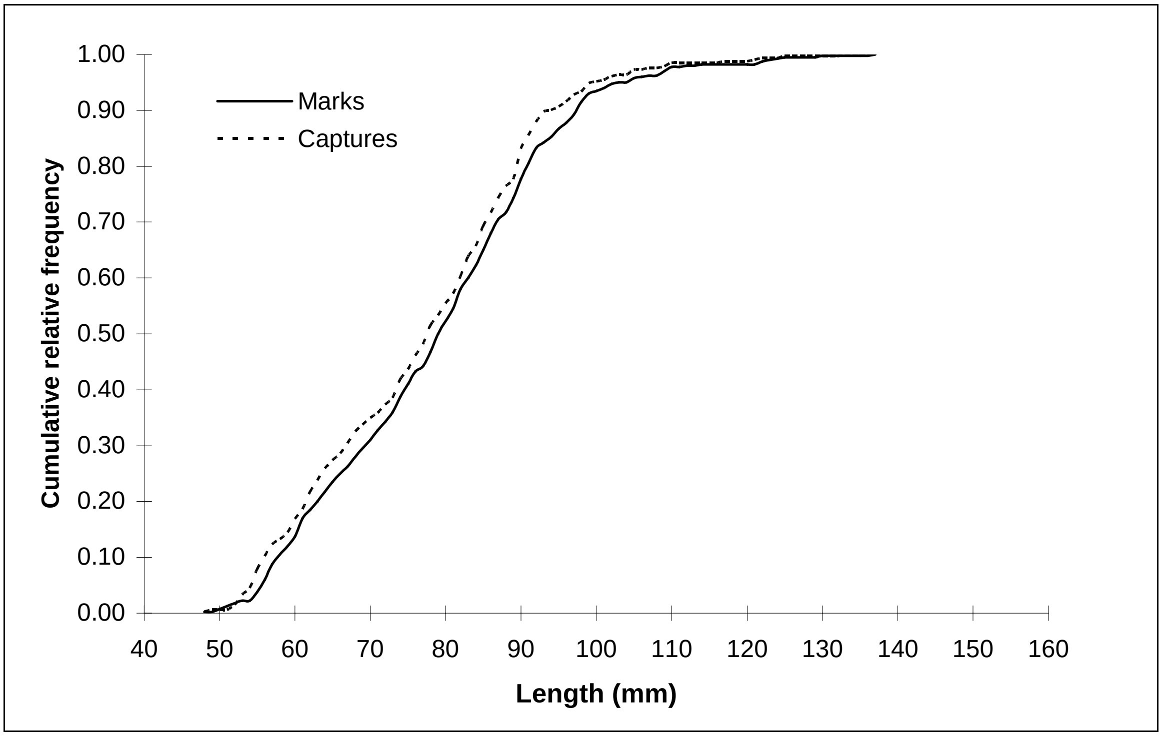

Figure 12.–Cumulative length frequency distributions of marks and captures at site 2 during the late winter.

events. Stratifying at the length that corresponded with the D_{max} statistic resulted in two strata: $\leq$ 65 mm and $\geq$ 66 mm. There were 94 fish $\leq$ 65 mm and 306 fish $\geq$ 66 mm captured during the 1st event, and 91 $\leq$ 65 mm and 241 $\geq$ 66 mm captured during the 2nd event; 2 of the 91 fish and 91 of the 241 were recaptures (Table 5). An estimate of the number of coho salmon $\leq$ 65 mm was not calculated because of the low number of recaptures. An abundance estimate of 807 (SE = 55) was calculated for coho salmon $\geq$ 66 mm; the relative precision of this estimate was 13% (Table 6).

Site 3 (Yandukin Drive)

Juvenile coho salmon captured averaged 108 mm and ranged in size from 50 to 152 mm (Figure 8). There were 80 coho salmon captured and marked during the 1st event, 34 captured during the 2nd event, and 9 of those 34 had marks from the 1st event (Table 5). Cumulative length frequency distributions of fish captured in the 1st event and those recaptured in the 2nd event were significantly different (KS test, D_{max}= 0.52, P < 0.02; Figure 13), but there was no significant difference between cumulative length frequency

Table 5.–Number of juvenile coho salmon captured and marked during the 1st event, number of coho salmon captured during the 2nd event, and number of coho salmon that were recaptures in the 2nd event of the mark–recapture experiment at each site for the late winter sample period.

	1st Event	2nd Event	
	Captured and marked	Captured	Recaptured
Site 1			
Total	157	-[a]	-[a]
Site 2			
$\leq$ 65 mm	94	91	2
$\geq$ 66 mm	306	241	91
Total	400	332	93
Site 3			
$\leq$ 93 mm	12	13	6
$\geq$ 94 mm	68	21	3
Total	80	34	9

[a] Second event was not conducted.

distributions of fish captured in the 1st event and those captured in the 2nd event (KS test, D_{max}= 0.25, P = 0.08; Figure 14). These results indicated that stratifying was necessary, so two strata were created ($\leq$ 93 mm and $\geq$ 94 mm). There were 12 fish $\leq$ 93 mm and 68 fish $\geq$ 94 mm captured during the 1st event, and 13 $\leq$ 93 mm and 21 $\geq$ 94 mm captured during the 2nd event; 6 of the 13 fish and 3 of the 21 were recaptures (Table 5). The estimated abundance of coho salmon $\leq$ 93 mm was 25 (SE = 4, RP = 35%; Table 6).

An estimate of the number of coho salmon $\geq$ 94 mm was not calculated because of the low number of recaptures. A small sample K-S test was performed to compare the length distribution of recaptures to that of captures. This test failed to reject the null hypothesis (D_{max} = 0.29, P = 0.48), implying that there was equal probability of capture in the first event. However, the unusually small sample size (9 recaptures) suggests there may not have been enough power to detect a difference if one did exist. Therefore, abundance of all fish using pooled data was not estimated.

MIGRATIONS AND MARK RETENTION

The following migration data must be taken as anecdotal observations because double marks were not used during the early winter study and no tag retention experiments were performed. There is no reliable way to extend an inference made from these documented migrations to the population as a whole.

Seven juvenile coho salmon migrated downstream from site 1 to site 2 between the early and late winter. One juvenile coho salmon migrated upstream from site 2 to site 1 sometime between early and late winter. Two coho salmon migrated downstream from site 2 to site 3 between early and late winter. Two coho salmon migrated upstream from site 3 to site 2 between early and late winter. Another juvenile coho salmon migrated from site 2 to site 1 sometime between the late winter sampling period for site 2 and the late winter sampling period for site 1.

There were 21 juvenile coho salmon marked in the early winter at site 1 and recaptured in the late winter at site 1. There were 180 juvenile coho salmon marked in the early winter at site 2 and recaptured in the late winter at site 2. Six juvenile coho salmon were marked in the early winter at site 3 and recaptured in the late winter at site 3.

There were 11 juvenile coho salmon marked at site 1 in early winter that were documented emigrating through the spring smolt weir. At least 53 coho salmon marked at site 2 in the early winter and 22 coho salmon marked at site 3 in the early winter emigrated through the weir. Five coho salmon marked in the late winter at site 1, 72 coho salmon marked in late winter at site 2, and 14 coho salmon marked in late winter at site 3 emigrated through the weir.

One adipose-clipped juvenile coho salmon was captured at site 3 during the early winter. Another two adipose-clipped juvenile coho salmon were captured at site 3 during the late winter. Two adipose-clipped juvenile coho salmon were also captured at site 2 during the late winter. All adipose-clipped fish contained a CWT indicating they were tagged at Jordan Creek in the spring of 2004.

Table 6.–Estimates of juvenile coho salmon abundance $(\hat{N})$ during the late winter for each study site at Jordan Creek in 2005.

	$\hat{N}$	SE	$\hat{N}$	SE	Pooled $\hat{N}$	SE	RP (%)
Site 1	-[a]	-[a]	-[a]	-[a]	-[a]	-[a]	-[a]
Site 2	$\leq$ 65 mm		$\geq$ 66 mm				
	-[a]	-[a]	807	55	-[a]	-[a]	13[b]
Site 3	$\leq$ 93 mm		$\geq$ 94 mm				
	25	4	-[a]	-[a]	-[a]	-[a]	35[b]

[a] No estimate was calculated

[b] The relative precision is for only one strata.

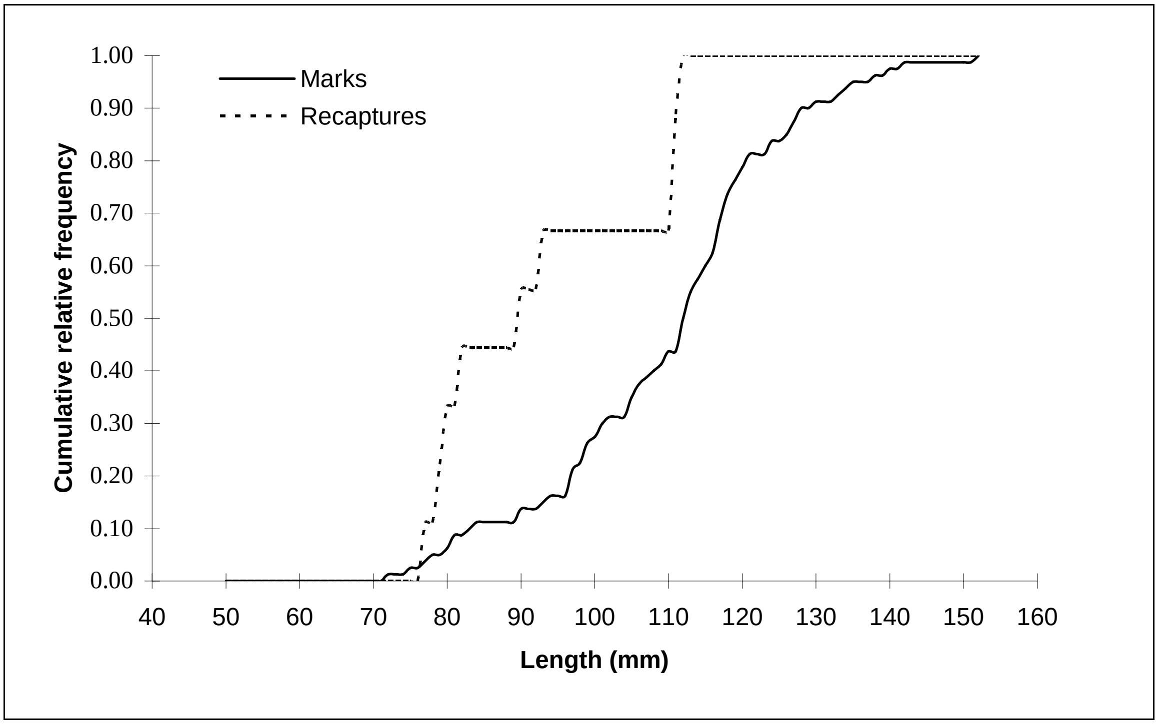

Figure 13.–Cumulative length frequency distributions of marks and recaptures at site 3 during the late winter.

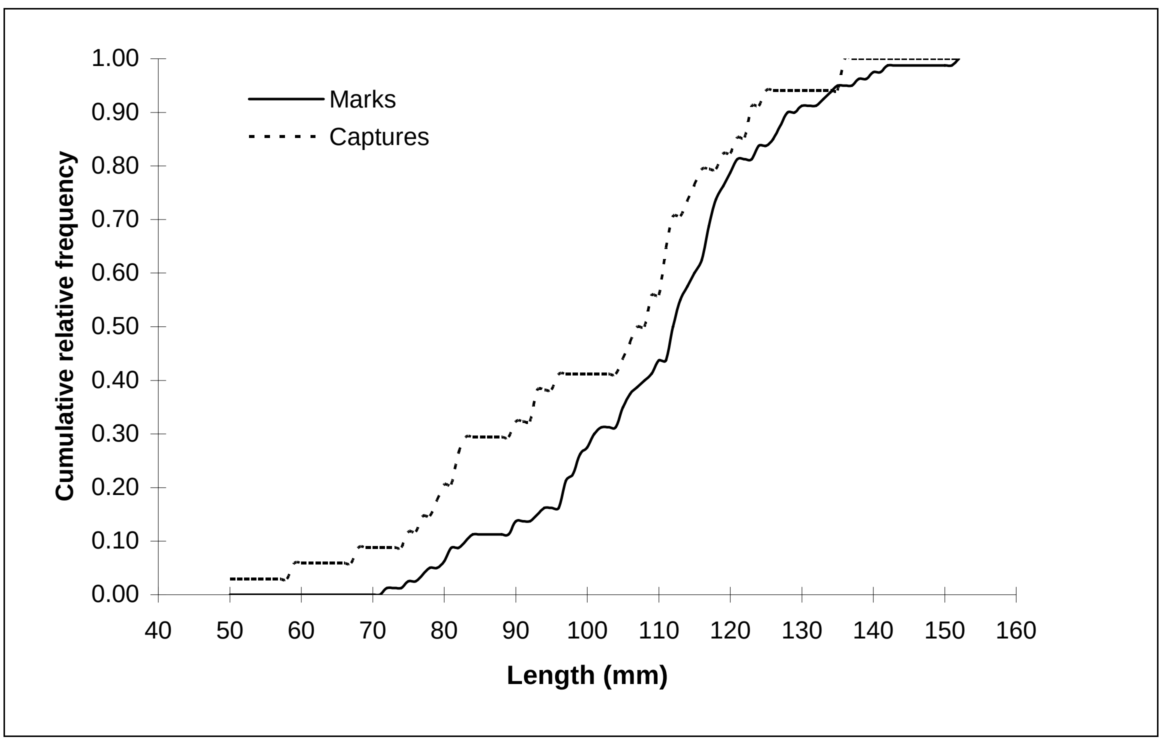

Figure 14.–Cumulative length frequency distributions of marks and captures at site 3 during the late winter.

Table 7.–Water temperatures at the time of trapping for each trapping event during the early and late winter.

	1st Event	2nd Event
Early winter		
Site 1	7.0°C	8.0°C
Site 2	2.0°C	6.0°C
Site 3	5.0°C	7.0°C
Late winter		
Site 1	5.5°C	-
Site 2	5.0°C	4.5°C
Site 3	2.5°C	1.5°C

Thirty-one of the 72 coho salmon from site 2 that emigrated through the weir were marked with both a LCP and a "V" brand. Forty had a LCP and no "V" brand, and one had a "V" brand and no LCP. Four of the 14 coho salmon from site 3 that emigrated through the weir were marked with both a UCP and a "T" brand while 10 had a UCP and no "T" brand.

WATER TEMPERATURE

Water temperatures in the early winter ranged from 7 to 8°C at site 1, from 2 to 6°C at site 2, and from 5 to 7°C at site 3 (Table 7). Spring water temperatures were 5.5°C at site 1, 4.5-5°C at site 2, and 1.5-2.5°C at site 3 (Table 7).

DISCUSSION

Problems were encountered at site 1 during early winter that led to imprecise and biased estimates. It rained 1.5 inches at the Juneau International Airport (JIA) from November 23 through 28 (NOAA 2006), and associated high stream flows breached nets that were blocking upstream and downstream boundaries of the site. This breach weakened the assumption that the site was closed to migration. There was a decrease in the numbers of coho salmon captured in the 2nd event when compared to numbers captured in the 1st event. This decrease may be indicative of fish being forced out of the trapping site by high flows. Alternatively, fish might not have been attracted to the bait during the 2nd event because they were allowed to eat the uncovered eggs in the 1st event. Eggs were covered with nylon mesh after this was discovered. The low numbers of fish captured and recaptured during the 2nd event resulted in an imprecise estimate. Further, the possible violation of the closure assumption and the reduced probability of capture in the second event for marked fish probably biased the estimate. A late winter mark–recapture experiment was not conducted at site 1.

Results indicate that coho salmon abundance estimates for site 2 were relatively precise. Site 2 had a higher abundance estimate than either of the other sites during both the early and late winter. Site 2 also contributed relatively more marked smolts through the spring weir than the other sites. General observations of the sites revealed that site 2 had more underwater cover (i.e. vegetation, rootwads, undercut banks, and large woody debris) than the other two sites. It also had much deeper pools than site 1 that could be important when the creek freezes. Cover and deep pools are critical for overwintering coho salmon (Bustard and Narver 1975; Heifetz et al. 1986; Murphy et al. 1986) because their metabolism slows and they migrate less during the winter.

According to the length frequency distributions, site 3 had the largest fish. Coho salmon abundance estimates for site 3 were relatively imprecise and unreliable. Significantly less coho salmon were captured in the 2nd event compared to the number captured in the 1st event at site 3 during the late winter. High stream flows could be the cause of these differences. It rained 1.45 in at JIA during the trapping period from March 8 through 10 (NOAA 2006), and fish may have been forced downstream out of the trapping area. If they were flushed downstream by more than about 100 m, they entered the intertidal portion of the creek. If flows were forceful enough, it is possible that fish entered the Mendenhall Wetlands estuary.

Previous studies have suggested that site fidelity of overwintering juvenile coho salmon is highly dependent on the exposure of the site to high water flows (Bell et al. 2001) and this was evident at Jordan Creek. Sites 1 and 3 were more exposed to high flows and it was reflected in the lower precision of their abundance estimates when compared to site 2. A few coho salmon migrated from site to site between early and late winter, which indicates that coho salmon populations within specific microhabitats at Jordan Creek are not closed populations during the overwintering period. One fish also migrated from one site to another over the course of one week during the late winter. The documented migration between sites was minimal, but a number of fish could have emigrated from the sites between sampling events and not been accounted for. The presence of coho salmon with CWTs suggests that some coho salmon emigrated from Jordan Creek in the spring and then immigrated back into the stream in the fall or winter. The geographic location of these tagged fish between the time they emigrate and immigrate is unknown, but it is speculated that they reside in the estuarine environment of Gastineau Channel.

Of the marks used, the finclips were easiest to observe and were more likely to be retained than other marks. The dye injector used too much pressure for fish of this size and it split the fins of many fish. When it split the fin, the dye was not embedded in the fin and the retention rate was substantially lower. The dye was clearly visible when a good injection did occur. Problems with dye marks were contrary to the successful results of Thedinga and Johnson (1995), who concluded that many colors of dye or paint were suitable for short term (< 6 weeks) coho salmon marking experiments, and orange acrylic paint or Alcian blue dye were more suitable for long term (> 6 weeks) experiments. A pressure-adjustable injector may solve this problem. Freeze brands were easily observable between sampling events within a sampling period. However, brands were sometimes difficult to observe when fish migrated through the weir months later. Many fish observed at the weir had secondary marks but did not have a brand. This can be partially explained by the fact that not all fish that were given a secondary mark were also branded. The metal of the brand may not have been cold enough to leave a noticeable brand on some fish at site 3 since members of the crew were still learning the branding technique, and the crew ran out of CO_2 and encountered equipment failure at site 2.

As a result of this study, it is apparent that changes in the trapping methodology need to occur before a thorough assessment of habitat use by juvenile coho salmon in Jordan Creek is conducted. An open population model would eliminate the assumption that immigration and emigration does not occur, thus providing more accurate information. An open population experiment requires unique individual tags (e.g. passive integrated transponder, or PIT tags) in place of batch marks. PIT tags have been successfully inserted into the abdominal cavity of juvenile salmon (Prentice et al. 1990; Bell et al. 2001). The use of PIT tags would also allow an estimate of overwinter mortality. In addition to changing the mark–recapture methods, microhabitats within Jordan Creek need to be characterized and mapped. Characteristics of the habitat that are important to juvenile coho salmon must be identified and quantified within each microhabitat. Once the entire creek is mapped into microhabitats, a stratified-random sampling design can be used to select the specific microhabitats to be assessed for coho salmon production.

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APPENDIX A. DETECTION OF SELECTIVE SAMPLING

Appendix A1.–Detection of size- and/or sex-selective sampling during a two-sample mark–recapture experiment and its effects on estimation of population size and population composition.

Size selective sampling: The Kolmogorov-Smirnov two sample test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first and/or second sampling events. The second sampling event is evaluated by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R) by using the null test hypothesis of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. A third test that compares M and C is then conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

Sex selective sampling: Contingency table analysis (Chi^2-test) is generally used to detect significant evidence that sex selective sampling occurred during the first and/or second sampling events. The counts of observed males to females are compared between M&R, C&R, and M&C using the null hypothesis that the probability that a sampled fish is male or female is independent of sample. If the proportions by gender are estimated for a sample (usually C), rather an observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are then compared between samples using a two sample test (e.g. Student's t-test).

M vs. R	**C vs. R**	**M vs. C**
Case I:		
Fail to reject H_o	Fail to reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during either sampling event.

Case II:

Reject H_o	Fail to reject H_o	Reject H_o

There is no size/sex selectivity detected during the first event but there is during the second event sampling.

Case III:

Fail to reject H_o	Reject H_o	Reject H_o

There is no size/sex selectivity detected during the second event but there is during the first event sampling.

Case IV:

Reject H_o	Reject H_o	Either result possible

There is size/sex selectivity detected during both the first and second sampling events.

Evaluation Required:

Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

-continued-

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test is likely detecting small differences which have little potential to result in bias during estimation. *Case I* is appropriate.

B. If a) sample sizes for M vs. R are small, b) the M vs. R p-value is not large (~0.20 or less), and c) the C vs. R sample sizes are not small and/or the C vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the second event which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

C. If a) sample sizes for C vs. R are small, b) the C vs. R p-value is not large (~0.20 or less), and c) the M vs. R sample sizes are not small and/or the M vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the first event which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation. D. If a) sample sizes for C vs. R and M vs. R are both small, and b) both the C vs. R and M vs. R p-values are not large (~0.20 or less), the rejection of the null in the M vs. C test may be the result of size/sex selectivity during both events which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation.

Case I. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

-continued-

If stratification by sex or length is necessary prior to estimating composition parameters, then an overall composition parameters (p_k) is estimated by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma} \hat{p}_{ik} \qquad (1)$$

and,

$$\hat{V}[\hat{p}_k] \approx \frac{1}{\hat{N}_\Sigma^2} \left(\sum_{i=1}^{j} \hat{N}_i^2 \hat{V}[\hat{p}_{ik}] + \left(\hat{p}_{ik} - \hat{p}_k \right)^2 \hat{V}[\hat{N}_i] \right) \qquad (2)$$

where: j = the number of sex/size strata;

$\hat{p}_{ik}$ = the estimated proportion of fish that were age or size k among fish in stratum i;

$\hat{N}_i$ = the estimated abundance in stratum i; and,

$\hat{N}_\Sigma$ = sum of the $\hat{N}_i$ across strata.

APPENDIX B. DATA FILES

Appendix B1.–Computer files containing Jordan Creek mark–recapture data from both early and late winter 2004-2005.

File name	Description
Data_Amalga.xls	All mark–recapture data including lengths for site 1 (Amalga St. site).
Data_Beaver Pond.xls	All mark–recapture data including lengths for site 2 (Beaver Pond site).
Data_Yandukin.xls	All mark–recapture data including lengths for site 3 (Yandukin Dr. site).

Appendix B2.–Computer files containing Kolmogorov Smirnov test data from mark–recapture experiment at Jordan Creek during early winter 2004–2005.

File name	Description
Amalga KS greater than 76.xls	Kolmogorov Smirnov tests for all coho captured at site 1 that were greater than 76 mm.
Amalga KS less than 77.xls	Kolmogorov Smirnov tests for all coho captured at site 1 that were less than 77 mm.
Amalga KS_all lengths.xls	Kolmogorov Smirnov tests for all coho captured at site 1.
Beaver Pond KS greater than 93 mm.xls	Kolmogorov Smirnov tests for all coho captured at site 2 that were greater than 93 mm.
Beaver Pond KS less than 94 mm.xls	Kolmogorov Smirnov tests for all coho captured at site 2 that were less than 94 mm.
Beaver Pond KS early_all lengths.xls	Kolmogorov Smirnov tests for all coho captured at site 2.
Yandukin KS greater than 112 mm.xls	Kolmogorov Smirnov tests for all coho captured at site 3 that were greater than 112 mm.
Yandukin KS less than 113 mm.xls	Kolmogorov Smirnov tests for all coho captured at site 3 that were less than 113 mm.
Yandukin KS early_all lengths.xls	Kolmogorov Smirnov tests for all coho captured at site 3.

Appendix B3.–Computer files containing Kolmogorov Smirnov test data from mark–recapture experiment at Jordan Creek during late winter 2004–2005.

File name	Description
Beaver Pond KS greater than 65 mm.xls	Kolmogorov Smirnov tests for all coho captured at site 2 that were greater than 65 mm.
Beaver Pond KS less than 66 mm.xls	Kolmogorov Smirnov tests for all coho captured at site 2 that were less than 66 mm.
Beaver Pond KS late_all lengths.xls	Kolmogorov Smirnov tests for all coho captured at site 2.
Yandukin KS greater than 93 mm.xls	Kolmogorov Smirnov tests for all coho captured at site 3 that were greater than 93 mm.
Yandukin KS less than 94 mm.xls	Kolmogorov Smirnov tests for all coho captured at site 3 that were less than 94 mm.
Yandukin KS late_all lengths.xls	Kolmogorov Smirnov tests for all coho captured at site 3.